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Improving Mathematics Learning and Teaching through Syllabus Change in a South African University Campus: ICT Leverage
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KEYWORDS curriculum change, student support, practicality of subject

ABSTRACT This paper presents the investigated effect of curriculum change on the student performance in first-year Mathematics modules at the Medunsa Campus of the University of Limpopo, South Africa. The change increased the syllabus scope intensely. However, when student examination marks in the old modules were compared with those of other students in the new modules, the new modules showed improvements on average marks. However, larger variances were indicated, which is diverse performance. Exploration as to why higher performance was achieved showed that speed in lecturer facilitation and student practice by using technology was the reason. What remained was to improve uniformity in performance, which was thus recommended by the study.

INTRODUCTION The original curriculum of mathematics at the former Medical University of Southern Africa (Medunsa) was designed with the help of the Department of Mathematics of the University of Pretoria (MDUP) in 1988. This curriculum was used until 2004 when Medunsa merged with the former University of the North (UN) to form the University of Limpopo (UL). The two Departments of Mathematics at Medunsa and Turfloop Campuses designed a new curriculum that would be consistent across the campuses. At the first level (Mathematics-1 modules) the syllabus entailed combining the previous syllabi that were used at the two universities since each one involved addition that would increase their modules slightly.

The two syllabi were about 90% common, which means that the portion added for each one was about 20%, which is a slight increase. Often when course content and scope increase, course demand usually increases while the pass rate decreases. However, at the Medunsa campus, the pass rates in Mathematics-1 were suspected to have increased. This prompted a former student to investigate formally if the pass rates had increased and also investigate the fundamental causes of the increases. Interest was to use statistical tests, and to determine the nature of the changes. This paper is based on that research on a study conducted on this (Molale 2010). The tutors who were involved during the study period were given a short training on the syllabus aspects that were new because they had not done them at first year.

The study purpose was to evaluate the effect of the structural changes of the Mathematics-1 curriculum on students' academic performance. The objectives were:

- To evaluate the level of performance for both syllabi.
- To compare the performance of Mathematics-1 students of 2005 to 2007 with Mathematics-1 of 2008 to 2010.
- To determine how facilitation managed to prevent a decrease in performance after an increase in syllabus coverage.
- To evaluate the significance of success and failure on the structure of the curriculum.

RESEARCH BACKGROUND

The campus of Medunsa of the University of Limpopo is located inside the former Medical University of Southern Africa (Medunsa). The natural sciences form a small percentage in a campus dominated by the health sciences (Dental Therapy, Medicine, Occupational Therapy, and Physiotherapy). Management of this campus pay more attention to the health sciences and little to the natural sciences. Historically, this campus was once a medical school without the natural science focus, except where the natural sciences served to support the health sciences. During the time (the late 1980s) that Medunsa was fully focused on the health sciences, a need was identified that local communities needed the services of a university in the sciences. The sciences for educators in education were the major lacks in the local communities. The faculty of basic sciences was established in year 1988 to fill this gap. However, the university still paid more attention to the health sciences, and the natural sciences had to struggle for many years. This was the case until the University of Limpopo was formed from the merger of the former Medunsa and the former University of the North. Nothing much was changed in the positive favour of the sciences. Even the initial leadership of the school of pathology and pre-clinical sciences which incorporated the basic sciences was coming from medicine. It was always difficult to show them that the sciences needed to be developed beyond the level at which they were being offered. Most of the students enrolled in the sciences are believed to be rejects of the sciences of other universities and rejects of the health sciences because of their low matric results.

Focus and concentration of support is biased towards the health sciences. Management of the natural sciences is based at the Turfloop campus, about 300 km from the Medunsa campus. On the Medunsa campus there are mainly administrators who usually never commit to decisions in favour of academics in the naturals sciences. Hence, the natural sciences are not visible enough due to lack of leadership on campus. As a result, academic personnel in the sciences have to produce enough results to demonstrate the existence of the sciences on this campus.

Mathematics is a core subject in the natural sciences. The first year level, mainly, is the level taken by many students in the natural sciences because most majors require mathematics. The pass rates were at some point low, until staff changes occurred in the department. During the high failure rate era at Medunsa, Statistics suffered because it depended on Mathematics for its majors. Hence, both Mathematics and Statistics, among other science majors, could not have many postgraduate students. Furthermore, they both could not attract many students as their value was also not even promoted. The Mathematics lecturer at the time of this study joined before the merger to form University of Limpopo. He saw the past pass rates in the era of failure in Mathematics. As a former teacher, and having done research in mathematics education, he focused on changing the mind sets of students in the sciences to realise the value of Mathematics.

This lecturer acknowledged in several research presentations that he struggled to shift the paradigms in students' minds which made Mathematics to be perceived as a 'barrier to a bachelor's degree attainment without value'. At the time the merger was due, and harmonisation of programmes was required. This happened, and apparently, the lecturer made some enquiries locally (i.e. in South Africa) and contacted some international and overseas networks that assisted him in the curriculum development for the new Mathematics-1 modules in both campuses.

The syllabus was seen as aggressive and ambitious since it was seen to be much more demanding for the type of students admitted at the Medunsa for studying the sciences. Some monitoring was placed in the delivery of the courses in this subject at the first year level. Seemingly, it was hoped or expected that the failure rate would drop dramatically. As a result, there was a close watch on the development of the teaching and the results of Mathematics-1.

Apparently, the first few years of offering these courses were difficult, but hard work was put into everything around the facilitation. Tutors were introduced to support students enrolled for Mathematics-1, and external monitoring was also included in the first years. The use of ICT teaching this level was also introduced. In the end the student results in performance at this level were not worse than before. This shocked many critics on campus, but in the Mathematics department this was seen as an indication of success and promising future. The Statistics department would stand to benefit from this because them the higher pass rate in Mathematics would influence more postgraduate admissions in Statistics. Moreover, high performance in this development was a benchmark for other subjects in the sciences, as it was known that the sciences had to produce many graduates of good quality to justify their existence in a health dominated campus. The improved performance in Mathematics-1 prompted this study.

The aspects that prompted this study were predominantly in performance (lecturer and students), throughput rate, benchmarking of best possible practices, practicality of mathematics subject and incorporation of technologies in teaching.

Student and staff performance

Lecturers are required to carry out their tasks and perform their job. They should also perform in their job. Their performance is the completion of the prescribed syllabus during an academic year, and such performance is measured against basic standards of accuracy and cost within the academic year, which then implies that some speed of performance should be attached to it (Rummler and Brache, 1995). When performance is not seen to be forthcoming, in the case of lecturing, the students usually perform poorly. However, mathematics lecturing on this campus inspired this study. Facilitation of Mathematics-1 showed an aggressive stand and bold attempts to do what is right, which is to improve standards to match global trends and also to improve the simplification of the subject right at the entry level.

In this context, student performance is a measure of the final examination results achieved by a group of students admitted in any given year. Poor performance is when the student results are lower than desirable in a given context while high performance entails meeting or exceeding the level that is desired. The difference between current performance and the theoretical performance limit is the performance improvement zone.

Therefore, performance entails determining the output of a particular process or procedure, and then modifying the process to increase the results. Performance improvement in this study was seen as the lecturer (individual performance) level as well as the student performance level. It is important in this paper to explain what enhanced or cause the performance in the Mathematics-1 class in general.

Student throughput

The term ‘throughput’ became fashionable in South Africa only after the 1994 democratic elections and the democratic era in the South African education landscape. Loosely speaking, throughput refers to the degree at which a goal is achieved. In education, student throughput is the rate at which an educational institution is able to produce graduates within the minimum required period of study in the courses for which they are registered (Botha, 2010). The low throughput is a single subject prevents students from achieving in large numbers. Hence, since in the Medunsa campus mathematics was a prerequisite for may subject, it was causing low throughput in the contexts outside the department as well. It was for this reason that the increase in passes in Mathematics-1 was viewed in the context of throughput that was expected to rise in the school of the sciences. This aspect is of interest to this study, and increased throughput is what this paper intended to contextualise.

Benchmark

For other departments in the sciences it was important for academics to benchmark the occurrences in the way the Mathematics-1 was handled from the time its curriculum was revised, to the lecture facilitation and student support that yielded improved results. Some modules in the school have higher failure rates than mathematics, and this has been a problem over the years. Statistics have over the years been admitting only few students who were performing well in Mathematics. As a result student performance was not a serious problem, and even though improvement was needed, it low performance was not severe. Biology, Chemistry, Physics and Psychology departments have been admitting many students in the past years. Failure rates in Biology and Psychology are experienced, but not severe. On the other hand, failure rates are seen to be severely high in Physics and much higher in Chemistry. These are the departments that were hoped to use the mathematics example for experimenting in their departments. This was a study to be benchmarked, since it became clear that practicality of the concepts, as well as continuous practice of problems solving enhance the improvement of performance (Carlson and Yaure, 1990; Cepeda et al. 2006).

The benchmarks are helpful in setting standards, especially in education and learning (Kornell and Bjork 2008). First, they may serve as the baseline from which improvement can be based. Some elements in the benchmarked models can be repeated while others can be improved. Also, where the contexts differ, there are usually possibilities of customising to ensure that the application suits the problem at hand.

Mathematics as a practical subject

From teaching experience and teacher training it shows that practical work in teaching enhances more understanding concepts (Kanyongo 2005). It also tends to improve engagement of students. The approach used in the Mathematics-1 was that if Mathematics is made practical, then students can acquire the knowledge and skills by more than texts, tutors and lecturer contact. However, by its nature, Mathematics is a concept driven subject and mathematical principles play a major role in teaching it. Therefore it takes an innovative perspective to rise above the usual modes of doing things (Teo and Wong 2000).

The question of innovation in the teaching of mathematics was not doubted. The lecturer impressed with the efforts and resources incorporated in the facilitation of the modules in this course. The use of many media in teaching can help to enhance the student performance (Vaughan 1998). It was just not trusted at the beginning mainly because the judgement was based on the past performances in the mathematics modules and the continued admission of students who had been refused admission in their earlier applications at other institutions or faculties. However, even if this was the case, the department of mathematics was determined to improve the pass rates and henceforth, the throughput. It is, however, understood that the practical aspect that makes students attentive most of the time.

Technology incorporation

Experience shows that students are passionate about technology and are using it increasingly in their search for more relevant information. Use of technology, where it applies, has shown to improve the speed at which work is completed, at an increased level of accuracy. Underwood (2009) informs that various technologies have been embraced extensively in sectors education. There are cases where technology has transformed teaching and learning activities to be more effective. Effective use of technology can also improve the lecturer in search of new methods of teaching and in different methods of facilitating certain mathematics concepts. Moreover, ttechnology enables students to become independent in the classroom.

The incorporation of technology use in the teaching of mathematics was done with challenges. There were few computers and students had to share the computers. It was important for this study to determine if the use of technology could have been seen as valuable in the improvement of teaching mathematics.

Curriculum Change

Curriculum change is universal, occurring to suit the times and the environment, and revolving around what works. It may occur due to external effects. It entails module shifts on syllabus, content, resources, examination and structure (Glatthorm 1987). Changing curricula occur for reasons such as to adapt to new technologies and be on par with the leading nations. Sensible curriculum changes are based on research, but many are based on political and other pressure. Subjective curriculum changes may be for personal gain. For example, changes could be made to accommodate an outside provider (of technology such as computer packages, textbooks, say) even though they were unnecessary. Such changes may not improve academic value. According to Gamoran (1997), the USA and Scotland had curriculum change to reform strategy. The curriculum exerts an important influence on student learning: A rich and rigorous academic curriculum promotes high levels of student achievement. Curriculum differentiation is associated with achievement inequality. Thus, curriculum change may be a potent policy lever. Upgrading curriculum quality may occur for low-achieving students. Mathematics is the study of quality, structure, space, and change seeking out patterns, formulate new conjectures and establish truth by rigorous deduction from appropriately chosen axioms and definitions (Graham 2002). It is relevant in modern education. It is vital as it permeates the daily lives of people globally. It is basic in modern inventions, scientific discoveries and research studies. Mastering basic mathematical skills aids to cope with life demands such as being numerically literate, gaining tools for employment, developing prerequisites for further education and appreciating the relationship between Mathematics and technology (Martin 2008). Also, Mathematics is a language of the sciences, and many disciplines depend on it as a symbol for communication. Thirdly, Mathematics is vital in developing students' general decision-making and problem solving skills (Lewis, Lazarovici and Smith 2001). Thus, more focus and research should be devoted to it.

The increased syllabus can lead to incompletion at the end of a semester. However, the use of technology to facilitate and practice mathematics exercises can increase the speed in subject delivery (Evangelista, 2000). There are many versions of information technology and communication (ICT) that South African universities use to facilitate the learning for longer hours and allowing for new methods and content for supporting the prescribed syllabus content. Therefore, a syllabus increase can be backed by an ICT tool. ICT usage, mainly e-learning and the use of internet in teaching have the benefits of increased coverage and speed when compared to normal teacher tell (Balanskat, Blamire and Kefala 2006).

Hargreaves (1995) informs that in 1989, teachers in South Korea protested when mathematics curriculum moved from compartmentalized to spiral-integrated approach because it led to the poor students' performance. The teachers were neither equipped nor prepared for the change. The change in mathematics curriculum should help in effective teaching of the subject. Ponte *et al*. (1994) cite a success in which implementing a new mathematics curriculum in 1990-1991 depended on the views and attitudes of the teachers and students. Kilpatrick (2009) counsels that curriculum change should be a personal journey for mathematics teachers. In Finland, severe drawbacks in the Finnish mathematics curriculum were the order and time allocated to different concepts and skills (Martio 2009). The changes in the mathematics curriculum were made to help people use Mathematics in everyday life, but the aim could not be realised.

METHOD

Quantitative research requires numeric responses (Michael 2006). In this study, it consisted of student marks, which are numeric. The qualitative data were the primary data, which were the explanations of the perceived differences in the two versions of the syllabi as narrated by the tutors. The study used three types of data sources; examination marks from records of students' examinations, tutors and lecturer of the modules. This enabled eliciting of views from the subject role players. Secondary data were student marks of the years 2005 to 2007 of the pre-changed modules to 2008 to 2010 of the post-changed modules. For authentication they were compared with the ones from the examination department. Primary data were obtained by interviewing the tutors of the modules in the years given, and the module lecturer, to give their impressions about the changes of the modules.

Participants

The tutors who were involved in the years 2008 to 2010 did the pre-change modules were the main respondents in the study. They were students of the pre-change modules, and they were involved as tutors of the post-change modules. The module lecturer was also consulted to verify the responses provided by the tutors.

Sampling

Tutors who did the pre-change modules and taught the post-change ones were the study respondents. A purposive sampling was used to select experienced people in the two versions of the syllabi. They had been involved in all modules. Purposive sampling is a nonprobability sampling method based on the targeted respondents' proficiency and/or experience with regards to the phenomenon in question (Babbie 2010). This sampling method was necessary because the participants were the only people who had the experiences beneficial to the study.

Analysis of Data

Quantitative Analysis: The four 2005 to 2007 modules were Differential Calculus (MATS111), Matrix Algebra (MATS121), Integral Calculus (MATS132), and Vector Algebra (MATS142). They were replaced by Differential and Integral Calculus (MATH101) and Elementary Set Theory, Matrices, Linear and Vector Algebra (MATH102). They were as follows.

Table 1: Descriptive statistics

	MATS111	MATS121	MATS132	MATS142	MATH101	MATH102
Mean	558.43	665.24	558.50	555.74	661.6358	665.0309
Standard Error	1.076	1.013	0.947	0.814	1.2016	1.17688
Median	660	666	559	554	662	668
Mode	445	669	445	550	663	550
Standard Deviation	114.40	113.136	112.240	110.099	114.76549	114.9792
Sample Variance	2207.38	1172.54	1149.818	1101.998	2118.0198	2224.3779
Kurtosis	--0.405	--0.360	--0.0215	--0.588	11.238383	--0.0765
Skewness	00.0074	00.127	00.0289	00.127	--0.68694	--0.4893
Range	663	662	661	444	886	779
Minimum	228	335	228	335	77	115

Maximum	991	997	889	779	993	994
Sum	110459	110960	99770	88584	99307	110535
Count	1179	1168	1167	1154	1151	1162
95% Confidence Level	22.124	22.001	11.870	11.608	22.374	22.324

Inspection of extreme values

The minimum two marks are found in the new modules. These are both low, but one is almost twice the other. The maximum values for the new modules are ranked second and third. They are also very close, which is desired in a change. Compared with the respective minimum marks, they show huge differences.

Inspection of means

On average, the marks of the old curriculum were lower (58.4, 65.2, 58.5 and 55.7) compared to those of the new curriculum (61.6 and 65.0). The problem is that the old module produce better results but have larger range values (86 and 79) compared to low ranges (63, 62, 61 and 44) in the old modules. The smallest range is 44 of the old module MATS142.

Skewness

The old modules marks were positively skewed and the new ones were negatively skewed. These indicate that for the old modules, there were more low marks than high marks while the new ones have more high marks than low marks.

Coefficients of variation

The coefficients of variations (CVs) are calculated by using the formula:

$$CV = \frac{s\tan dard \;\; deviation}{mean} \times 100\% \qquad (1)$$

From the standard deviation and mean values of Table 1 the following table present the CV based on equation (1) above.

Table 2: Coefficients of variation of the modules

	MATS111	*MATS121*	*MATS132*	*MATS142*	*MATH101*	*MATH102*
Coefficients of variations	20.4860%	17.0068%	20.0967%	19.8112%	17.3457%	17.2893%

Low CV value indicates that the values are more stable, and thus desirable. The 'desirable' CV value is 17.01% in the old module MATS121. The highest CVs are found in the old modules. New modules show low and comparably close CVs. They are the second and third smallest among all the CVs. Thus, the marks in these modules are near each other. This contradicts the range values found for the marks of these modules. It still serves as a good sign that these two modules are stable.

CVs for grouped modules

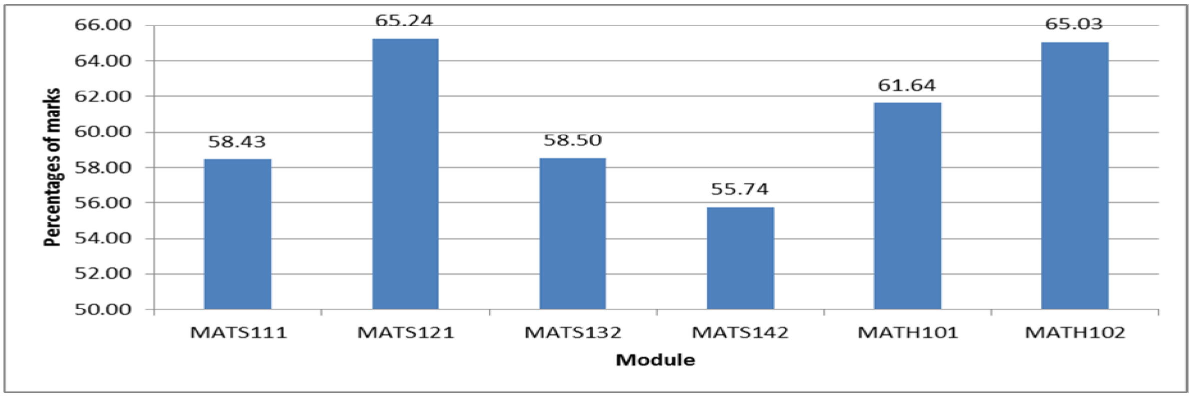
Table 3: Comparison of coefficients of variations of old and new modules

	Old modules	**New modules**
Mean	60.6789	60.8693
Standard deviation	16.6645	14.0033
CV	27.47%	23.08%

The combined marks for the new modules have a lower CV than the combined ones for the old modules. Thus the relative stability of marks is more in new modules.

Visual Display of Marks

Figure 1: Average marks of old and new Maths 1 curriculum



Visual inspection: Figure 1 shows that MATS121 (of old curriculum) is almost equal to MATH102 (in new curriculum). Two new modules were almost equal at about 58% each. Two new ones show to be disparate; one average mark in the new curriculum exceeds 60%, and the other exceeds 65%.

Outliers in old modules: The graph shows that the average for MATS121 is much higher than other averages.

Analysis of variance

Table 3

ANOVA *for the six modules*

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12142.41	5	2428.482	13.52768	8.84559E-13	2.223282
Within Groups	175031.52	975	179.5195			
Total	**187173.93**	**980**				

ANOVA tests the null hypothesis of equal means in all six modules. The test statistic 13.53 exceeds the critical value 2.22. We reject the hypothesis of equal means.

Table 4: ANOVA for the four old modules

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8078.197	3	2692.732	16.83533	1.5E-10	2.618318

Within Groups	106203.7	664	159.9453			
Total	**114281.9**	**667**				

ANOVA tests the null hypothesis H_0: Equal means for the four old modules. The test statistic 16.84 exceeds the critical value 2.62. We thus reject the hypothesis.

Table 5: ANOVA for two new modules

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	900.852	1	900.852	4.07052	0.044496	3.871533
Within Groups	68827.81	311	221.3113			
Total	**69728.66**	**312**				

ANOVA tests the hypothesis of equal means for the two new modules. The test statistic 4.07 exceeds the critical value, 3.87. We reject the hypothesis.

Qualitative Analysis

Application bias: The tutors stated that the syllabus aspects added were of applied nature. These aspects tied well with the previous abstract and impractical version, and formed a base to introduce the modules. The tutors stated that the new syllabi were more motivational. The changes also increased student interest. The lecturer stated that the student numbers increased dramatically. Also, the lecturer stated that student support improved with the increase in the number of tutorials.

ICT benefit

The main finding that assisted in the speed of facilitation was the use of blackboard, an ICT tool for lecturer facilitation and student practice. ICT support was attributed to searching for more understanding when students were stuck in the lecturer’s absence, mainly in the evenings and on weekends as well as during university holidays. In addition to the exciting syllabus content that was linked with practical material, ICT also increased the interest in learning the subject. Thus, ICT support expedited learning by providing student guidelines for understanding content quicker and provided hints and tips that made learning exciting and easy to grasp.

The positive aspect of ICT support is also that there was complete agreement from parties involved (students, tutors and the module lecturer) that this tool made a major difference in the subject delivery and recommended its future use. Using technology assisted in speedy facilitation and wider coverage. It was also hailed for enabling more alternatives to approaches to various concepts, and giving interesting illustrations.

The respondents indicated that some concepts which were difficult to learn in the past were also made easier by using technology. This was mainly due to diverse alternatives given on same concepts for illustrations and the different wordings to state the same aspects.

RESULTS

The study showed that the new syllabi statistically improved pass rates for individual modules and for the entire syllabus even with the extended syllabus scope. Reasons identified for the improved results are the syllabi entailing practical aspects, and placing these modules early in teaching. The use of technology in facilitating helped in speeding up larger content within the same period in which less content was given. It also assisted in more understanding and ultimately, to completion of the entire increased syllabus scope with more understanding and increased passes. Placement at opening stage also helped to improve the overall course presentation. These initiatives provided a new outlook to the modules, increasing student interest and motivation. For the lecturer, the changes posed a challenge to keep the standard high. Also, there was revived lecturer energy due to the syllabus changes. Lastly, student numbers increased in the subject. The study found that the increased syllabus was followed by ICT support, even on concepts that were initially taught manually. The student results improved dramatically. This was due to the speed in ICT usage, the ease of presentation and wider coverage as well as interesting and applied aspects of the syllabus content. The technology was the main key to all these benefits.

RECOMMENDATIONS

Practical subjects tend to appeal to students, especially if the application is within the student’s reach. It is recommended that academics should;

- Keep changing the module to suit times and match the changes;
- Expose the practical inclination of the subjects they teach;
- Ensure that there is adequate student support in the teaching and learning of all the courses; and

- Support the facilitation with modern ICT teaching tools in line with global trends.

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